"Geronimo" Cruises Entire Gulf of Mexico in Late Winter

By Reed S. Armstrong and John R. Grady*

BCF's R/V Geronimo, Galveston, Texas, has completed the first in a series of hydrographic surveys of the Gulf of Mexico (Cruise 12). The immediate purposes of these surveys are to describe the circulation and stratification in the Gulf of Mexico and to analyze the time variations of Gulf waters. Additional, long-range, goals are to relate the state and variations in the waters to the driving force (the atmospheric circulation), and to predict the circulations and characteristics of the waters. We intend to occupy about 135 hydrographic stations, sampling from the surface to the bottom, over all the Gulf during each cruise. Bathythermograph casts--and standard meteorological observations and radiation measurements for heat budget analyses--are made routinely along the cruise route.

During this first "all Gulf" cruise (Feb. 20-April 1, 1967), continuing problems with the ship's navigational gear curtailed operations in the eastern Gulf, but the cruise plan was rearranged to accomplish a rather comprehensive survey of the entire Gulf. We occupied 114 hydrographic stations and collected surface salinity samples and made bathythermograph casts at 281 stations.

We had planned to make vertical plankton hauls to 100-m. depth with a $\frac{3}{4}$-m. Hansen net at each hydrographic station--and to make vertical plankton hauls to near the bottom in the deeps of the Gulf with a Gulf V sampling net. Because of almost continuously poor weather and high seas, only 87 shallow and 2 deep plankton hauls were made.

This cruise was very successful, particularly because it was only the second time the entire Gulf of Mexico has been surveyed during one cruise operation. (The first was by the R/V "Hidalgo" of Texas A & M University in Feb.-March 1962.)

As the data are processed and analyzed, numerous interesting features of the Gulf waters are noted in surface distribution of the various water properties.

The circulation pattern of the surface waters can be inferred from the surface temperature distribution (fig. 1). Warm water (more than 24° C.) from the Caribbean Sea is the main driving force for the circulation throughout most of the Gulf. The water enters the Gulf along the western side of the Yucatan Straits and streams north to about 28° N. latitude. It then turns sharply to the south and, after following a rather intricate path, leaves the Gulf through the Florida Straits.

Some of the water entering the Gulf returns as countercurrents, in a series of eddies, on the western side of the Yucatan Straits. Other Caribbean water encounters an apparent countercurrent from the Florida Straits off the coast of Cuba, thereby setting up the clockwise-rotating eddy of the "C"-shaped cell of water more than 26° C. The flow from the western edge of this eddy to about the center of the Yucatan Straits is moving south, back in the Caribbean. The remaining water coming into the Gulf seemingly moves westward across the Campeche Shelf and then turns northeastward to join the main flow.

The circulation of the eastern Gulf of Mexico is reacting directly to the looping flow that enters through the Yucatan Straits and departs through the Florida Straits. Interaction of this loop current with adjacent waters establishes the circulation over most of the western Gulf. The general easterly and northeasterly flow in the western Gulf is probably also associated with the prevailing south and southeast winds over the area. The small pockets of cool water near shore may be associated with river discharge and land runoff.

Three particularly significant features are apparent from the temperature distribution: (1) the presence of a southward flowing countercurrent through the Yucatan Straits; (2) the lack of offshore penetration of Mississippi River discharge; and (3) the turbulent characteristic of oceanic circulations, as evidenced by the presence of numerous eddies, particularly those lining the boundary of the main flow of the loop current.

The distribution of surface salinity (fig. 2) almost exactly follows the temperature patterns. The Caribbean water in the eastern

*Research Oceanographers, BCF Biological Laboratory, Galveston, Texas.

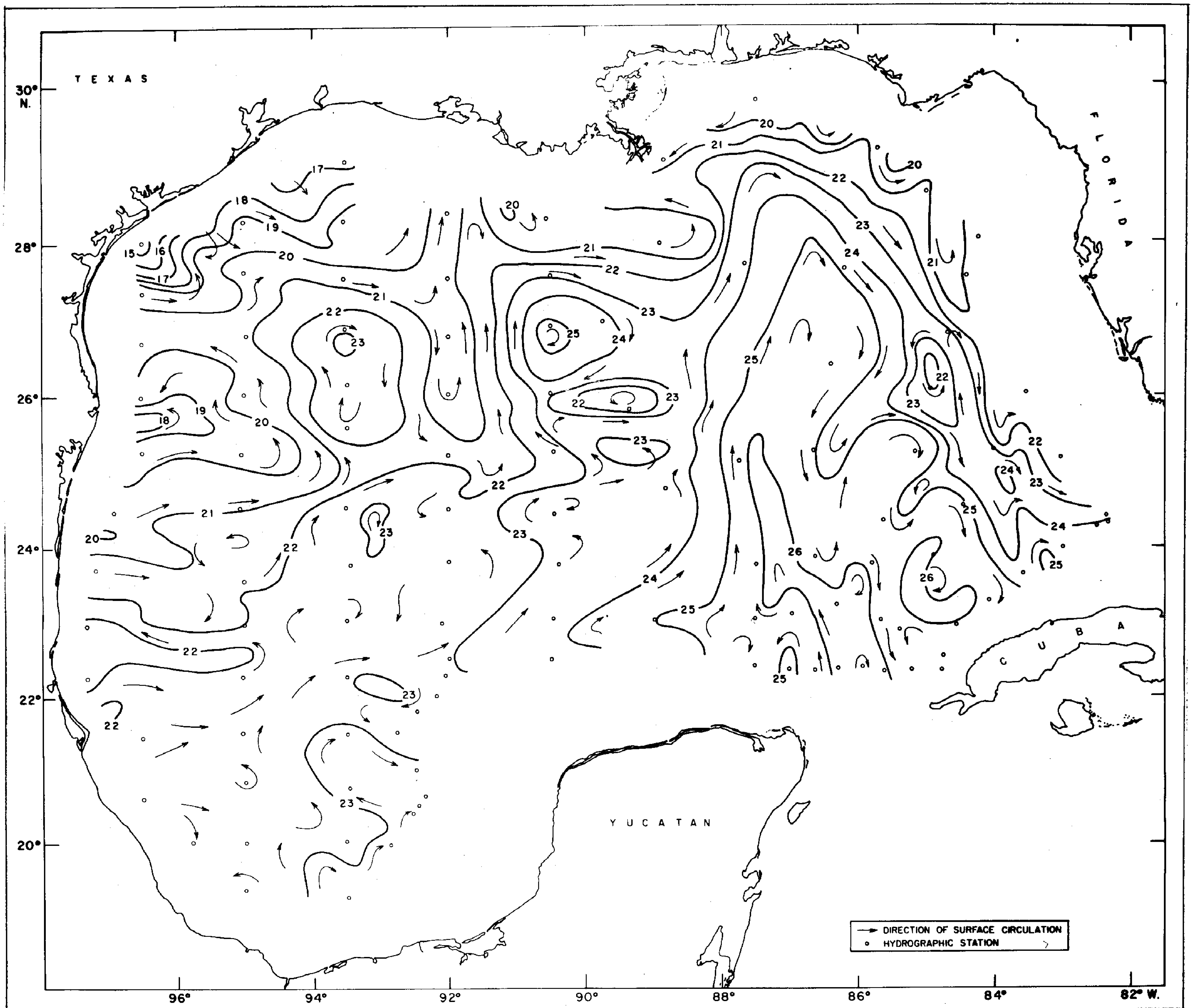

Fig. 1 - Surface temperature distribution (° C.) and the associated pattern of the surface circulation from Cruise 12 of the R/V Geronimo (February to April 1967).

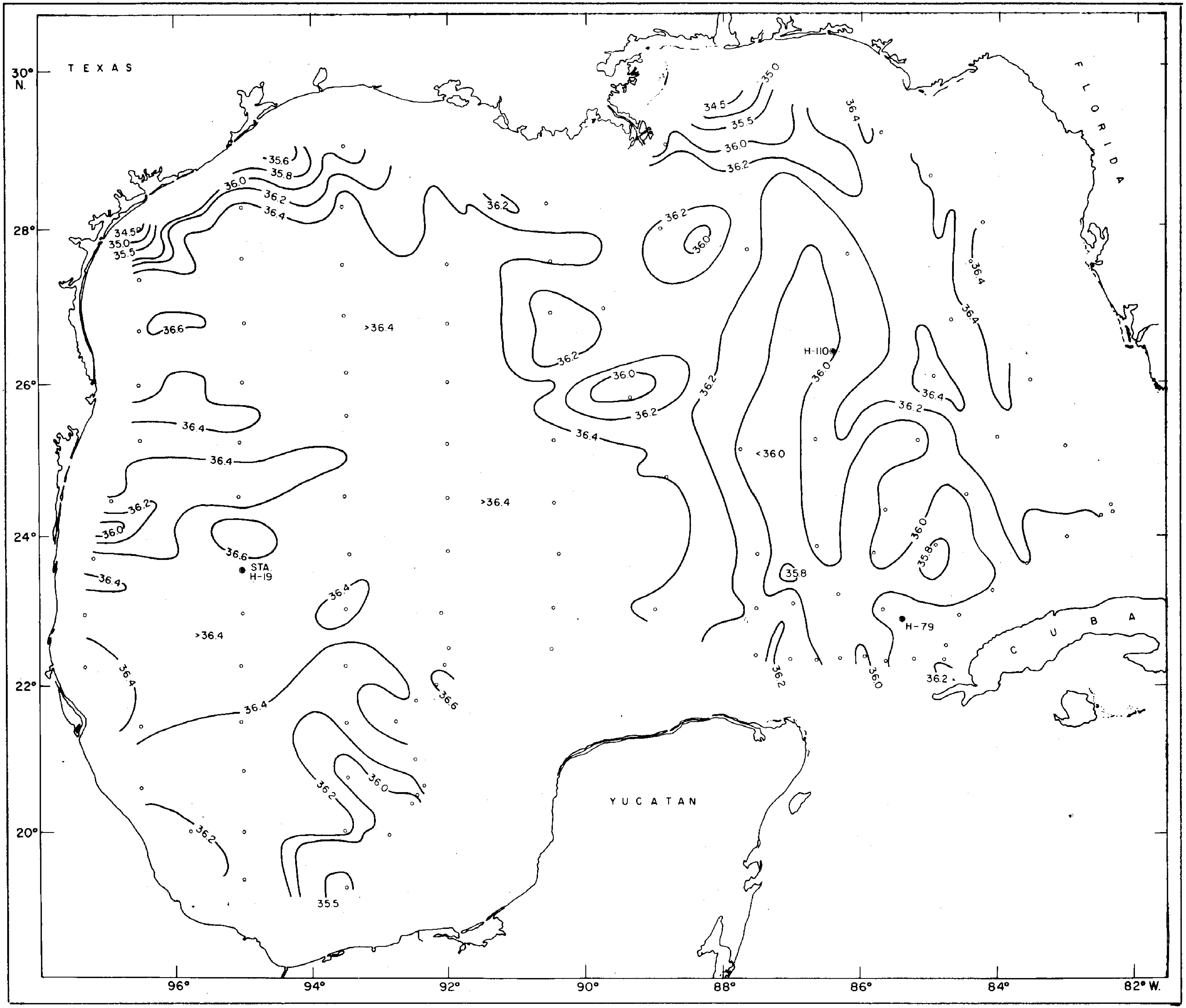

Fig. 2 - Surface salinity distribution (p.p.t.).

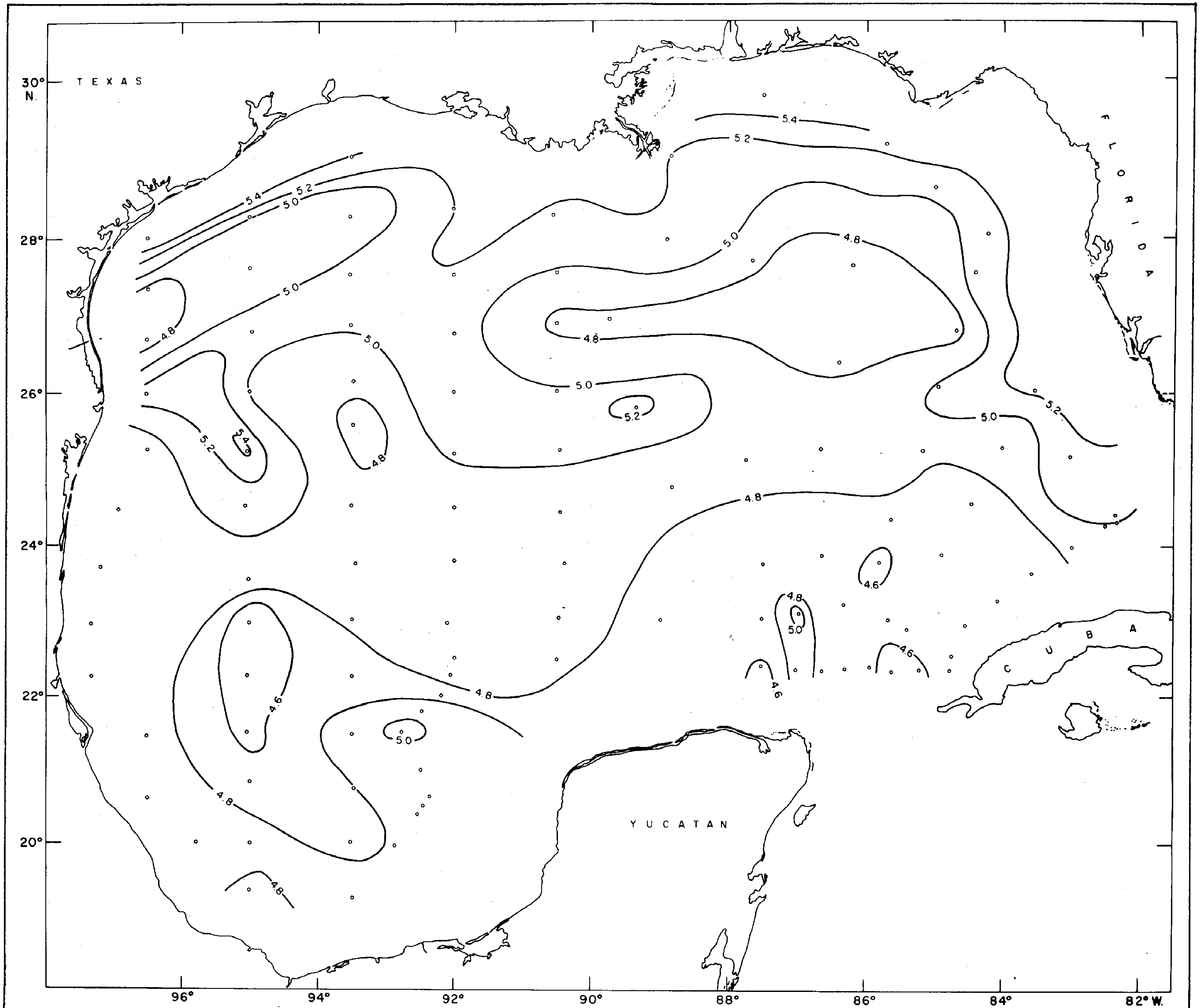

Fig. 3 - Surface oxygen distribution (ml./1.).

Gulf is easily distinguished by its low salinity; 36 parts per thousand (p.p.t.). The rather direct influence of the loop current is delineated by the 36.4 p.p.t. contour in the central part of the Gulf along a north-south transect. The offshore surface waters of the western Gulf are of high salinity (more than 36.4 p.p.t.) in contrast to the low salinity in the eastern Gulf.

The extensions of river discharge and land runoff are well defined by the low-salinity cells in the northwestern corner, to the east of the Mississippi Delta, and in the southeastern sector of the Gulf of Campeche.

The distribution of the dissolved oxygen content of the surface water (4.40 to 5.55 ml./1.) throughout the Gulf (fig. 3) is more similar to the distribution of temperature than of salinity. In the eastern Gulf, surface oxygen has a clearer relation to the currents and the distribution of other water properties than in the western Gulf, which is complicated by the eddy systems.

The dominant feature of the distribution of oxygen at the surface is the lower oxygen content of water of the large looping flow of the eastern Gulf. The relatively low oxygen content of the water entering the Gulf through the Yucatan Straits (about 4.48 ml./1.) accounts for the distinctively lower values in the eastern Gulf.

An interesting feature of this distribution is a westward-extending lobe of water from the eastern loop. This water has probably been entrained by the counterclockwise eddy north of the Campeche Bank and drawn to the west.

The vertical structure of the waters in the Gulf is exhibited by the profiles of salinity, temperature, and dissolved oxygen for three representative stations in the western Gulf, eastern Gulf, and Yucatan Straits (fig. 4).

The surface layers in the western Gulf are characterized by high salinity and low temperature, and the waters in the eastern Gulf have the lowest salinity and highest temperature. Oxygen contents of the surface waters are almost identical for the three areas.

The sharp salinity increase toward the salinity maximum layer (about 100-200 m. depth) produces a highly stabilized stratification.

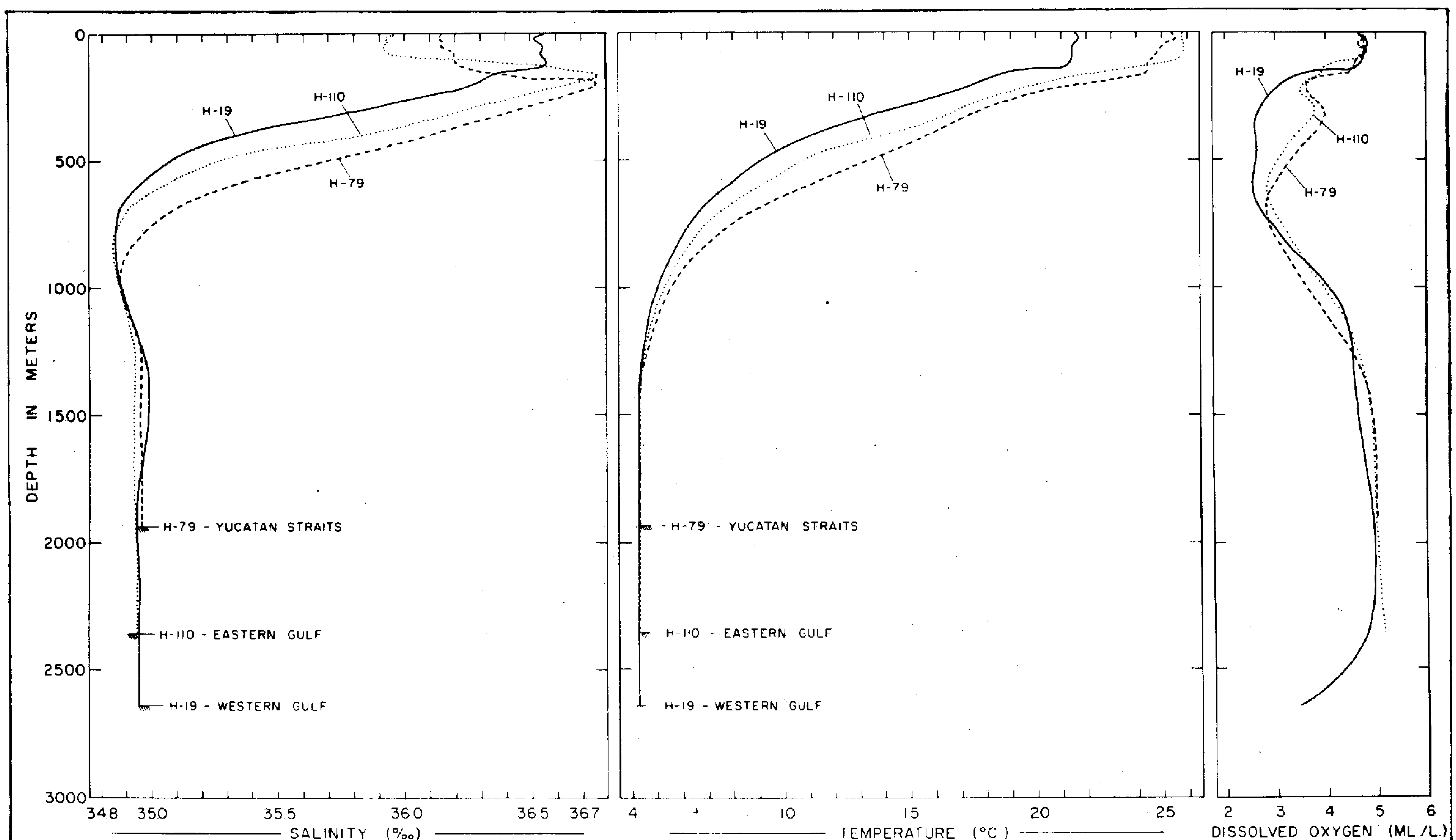

Fig. 4 - Vertical profiles of salinity (p.p.t.), temperature (°C.), and dissolved oxygen (ml./1.) representative of major marine areas of the Gulf of Mexico. See fig. 2 for station locations.

Because the high salinity water within and below this layer cannot come in contact with the air, the decrease in oxygen is pronounced through the layer. The western Gulf station has no significant subsurface salinity maximum, but a strong temperature gradient exists (about 150 m.), which has the same effect on stability.

The following points, apparent from the vertical profiles, help to interpret the surface circulations.

(1) In the western Gulf:

(a) If water is upwelling (as with a counterclockwise curving flow--surface divergence), low-temperature, low-salinity water is brought toward the surface.

(b) With convergent flow, warm, high-salinity water is collected.

(2) In the eastern Gulf:

(a) Surface divergence brings high-salinity, low-temperature water to the surface.

(b) Surface convergence acts to collect the low-salinity, warm water.

As many as four water masses are evident in the Gulf waters from the station profiles.

(1) Subtropical Underwater--defined by the salinity maximum layer (apparently absent at the western Gulf station).

(2) Sub-Antarctic Intermediate Water--core at the salinity minimum layer (750 to 950 m.). This water mass is also in the region of the oxygen minimum layer.

(3) North Atlantic Deep Water--characterized by the deep, secondary salinity maximum. The western Gulf is the only station of the three that exhibits this water mass (1,400-m. core depth).

(4) North Atlantic or Antarctic Bottom Water--secondary salinity minimum layer underlying the North Atlantic Deep Water.

The presence of what appears to be bottom water was unexpected because the sill depths of the Yucatan and Florida Straits are considerably less than the depth of this water mass. Examination of the deep waters at the other stations is required to determine whether or not this water mass is truly present in the Gulf. The low oxygen values in the deepest waters of the western Gulf station indicate the water has been out of contact with the atmosphere for a considerable time.